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Data Gathering Application for Ecological Mapping of Green Spaces

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Resumo

O processo de mapeamento ecológico envolve a classificação biogeográfica de zonas geográficas e a criação de mapas ecológicos para descrever padrões de componentes biológicos das áreas estudadas. Atualmente é realizado manualmente por especialistas e com recurso a imagens de satélite. Nesta dissertação, será abordado o desenvolvimento de uma aplicação móvel realizada no âmbito de um projeto conjunto entre o LASIGE e o cE3c (Centro de Ecologia, Evolução e Alterações Ambientais), ambos pertencentes à Faculdade de Ciências da Universidade de Lisboa (FCUL).

Este projeto tem enquanto objetivo principal desenvolver uma aplicação móvel Android para a recolha de dados ecológicos – como por exemplo, o tipo de vegetação e árvores, ou o pavimento, entre outros – que são úteis para a gestão e manutenção de zonas verdes urbanas, assim como os parques e outros locais, através de participação de cidadãos. Para cumprir este objetivo, desdobram-se os seguintes objetivos específicos: (1) Desenhar e implementar uma aplicação móvel através de plataformas que permitem a implementação no sistema operativo Android; (2) Desenhar e implementar uma aplicação web que permite a gestão e manutenção e que entidades parceiras adicionem pontos geolocais de interesse, e realizem o download e upload dos dados; (3) Desenvolver uma base de dados que permita o armazenamento e gestão da informação da componente 1 e 2; (4) Avaliar os protótipos através de testes com especialistas do cE3C e com um utilizador na cidade de Génova, Itália.

No desenho desta aplicação, que mobiliza crowdsourcing e visa ser uma ferramenta para ciência cidadã, contemplaram-se elementos de gamificação da tarefa de recolha de dados, de forma a facilitar as tarefas, motivar e dar feedback aos utilizadores acerca do seu progresso individual e, caso pertença a uma instituição de ensino parceira do projeto, dentro do seu grupo ou domain (uma base de dados especifica). Para dar este feedback acerca do progresso dos utilizadores, foram implementados elementos de visualização de recolhas já realizadas no mapa e também um Leaderboard, que mostra o progresso dos utilizadores no seu domain. No desenho da aplicação móvel, teve-se em conta que os utilizadores são cidadãos na personalização dos seus perfis e assegurou-se a segurança e anonimidade dos dados. Perspetiva-se que em projetos futuros do cE3c e LASIGE conjuntos com instituições Europeias, os dados recolhidos por esta aplicação sejam utilizados no desenvolvimento de modelação de aprendizagem neural profunda

para a deteção de áreas verdes em observações de dados capturados por satélite. Para efeitos desta tese, o desenvolvimento da rede neuronal não será abordado.

Na primeira fase do projeto, foi realizada uma revisão da literatura nas áreas de crowdsourcing, gamificação, e mapeamento ecológico; que ajudou a perceber os requisitos necessários para o desenvolvimento da aplicação, que tipo de crowdsourcing seria utilizado, e também o que seria importante para gamificar a aplicação de modo a ajudar os utilizadores a realizar mais avaliações dos espaços verdes urbanos. Em relação aos métodos utilizados neste momento, percebeu-se que o mapeamento é feito manualmente através de mapas vetoriais por profissionais em ecologia. Realizou-se ainda nesta fase como seria o desenvolvimento da aplicação, quais ferramentas seriam utilizadas, quais linguagens de programação seriam as melhores para cada fase do projeto, qual seria a melhor base de dados para a aplicação, e as linguagens de programação que poderiam ser usadas para o desenvolvimento das aplicações. Neste sentido, foi realizado um levantamento dos requisitos das aplicações, a infraestrutura que seria necessária para a implementação e a base de dados que iria ser utilizada – que para este projeto seria utilizar uma base de dados em Firebase Realtime Database. Nesta fase, foram identificadas algumas limitações, e realizadas decisões para as ultrapassar; optou-se por somente desenvolver para o sistema Android.

Na segunda fase do projeto, foi desenvolvida a aplicação móvel em Android, e foram implementados vários protótipos funcionais, que foram testados ao longo do projeto. Foi utilizado o sistema de mapas da Google utilizando a API especifica, alterando vários dos botões de base para que funcionassem com a aplicação e com os requisitos estabelecidos na primeira fase do projeto. Nesta fase, a base de dados foi também desenvolvida, para armazenar todos os dados de utilizador, os dados das avaliações dos pontos ecológicos feitos pelos utilizadores, e também os dados fixos para a aplicação que serão utilizados para efetuar as ligações através da aplicação (domains). A base de dados também foi criada de forma que os dados requisitados pudessem ser filtrados, através de *indexing*, pois as bases de dados Firebase guardam dados em formato de JSON. A aplicação utiliza vários API’s do sistema Android, como o sistema de GPS, e também utiliza a cache da aplicação para guardar informação. Foi também implementado um método que garantia que a informação da avaliação ecológica seria feita se o utilizador não tivesse acesso à internet quando estivesse a fazer as avaliações, em que guarda os dados para o envio quando tiver acesso.

Utilizando um protótipo funcional, foi feito um teste da aplicação com especialistas na área de ecologia da cE3c, com vários dispositivos móveis com várias características, e níveis de API de Android diferentes que ajudaram a identificar problemas e melhorar a aplicação. Também foram feitos testes de usabilidade, e de conteúdo para as avaliações ecológicas. Nestes testes foram identificadas alterações a nível de usabilidade, como também adições ao conteúdo das avaliações, e a inclusão de nomes de utilizadores para ajudar com a gamificação da aplicação. Os testes também ajudaram a identificar várias funcionalidades que podiam ser implementados no futuro, após a terminação desta tese, que estão resumidos nas conclusões. Nesta fase, a aplicação foi testada brevemente em Génova, Itália por um utilizador, que acabou por não conseguir realizar os testes necessários, devido às restrições da pandemia COVID-19, até à data de entrega desta tese.

Na terceira fase do projeto desenvolveu-se a aplicação Web que serve de suporte para a aplicação móvel, e foi implementada em HTML, CSS e JavaScript. A base da aplicação web foi desenvolvida com os estilos em CSS que permite a aplicação ser utilizada em dispositivos móveis e desktop, usando um layout reativo que verifica o tamanho de ecrã. A ligação à base de dados, como também o upload, e download de ficheiros CSV e XLSX foi desenvolvido através de bibliotecas disponíveis em JavaScript e scripts criados especificamente para a aplicação. A aplicação Web teve várias iterações até estar de acordo com as especificações, e os requisitos dos utilizadores que iriam utilizar a aplicação. Nesta fase foi também alterada a estrutura da base de dados em Firebase para garantir que a informação que seria descarregada através da aplicação estaria em ordem com as necessidades dos especialistas para puderem utilizar. Através da aplicação web, os moderadores da aplicação podem criar vários domains

Ambas as aplicações funcionam em conjunto, uma que o utilizador da aplicação web controla o acesso à aplicação pela criação de domínios, que os utilizadores da aplicação móvel têm de utilizar para poder aceder à aplicação. Esta aplicação web serve de modo para os especialistas puderem descarregar todas as avaliações efetuadas pelos utilizadores da aplicação móvel.

No final desta dissertação, são sugeridos potenciais trabalhos futuros que podem ser desenvolvidos para as aplicações, como também novas funcionalidades que podem servir melhor os utilizadores. Incluem-se aqui as contribuições ao projeto, e as competências adquiridas através do desenvolvimento das aplicações, e a tese.

Palavras-chave: Aplicação móvel, Ciência cidadã, Mapeamento ecológico, *Crowdsourcing*, Gamificação

Abstract

Throughout the process of ecological mapping, the tools used for this mapping have been primarily done via localized mapping by people with the help of satellite imagery. The aim of this project is to develop a mobile phone application which collects data on the structure of vegetation and presence of aquatic habitats in urban green areas. The application will be developed through platforms which allow implementation on the Android operating system. The implementation contemplates the gamification of the data collection task by various institutions across Europe. The application will have gamified mechanics to help with motivation when it comes to data gathering similar to many crowdsourced applications. A web application has been developed to aid the management of the application. Along with this, details on the technologies used (software), implementation, as well as the architectures of the developed systems will be presented – including the web application, mobile application, and the database structuring. Finally, the application was tested by experts, through a series of objectives and tasks that were assigned to receive feedback, which was then used to alter some features, and make room for new ones in the future.

Keywords: Mobile Application, Citizen Science, Ecological Mapping, Crowdsourcing, Gamification

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Chapter 1

Introduction

This project was developed for the Master's degree in Informatics at the Faculty of Sciences, University of Lisbon (FCUL) as a part of an internship (UIDB/00329/2020) with the cE3c (Centre for Ecology, Evolution and Environmental Changes) team of the University of Lisbon to be accomplished at the LASIGE research unit, of the Department of Informatics.

The project aimed to develop a mobile application for the cE3c team in order to facilitate citizen science, by providing a medium for scientists and regular citizens to collaborate in the mapping of ecological sites and gathering ecological data. Through the application, users visit various ecological points and review them to better understand their surroundings.

In order to map ecological points around the world, the cE3c team will be using the data gathered from the application via the users to create algorithms for machine learning to map other ecological areas.

1.1 Motivation

Managing the land base for environmental sustainability requires information about the current status and potential future status of these lands. This sort of key data can be gathered through scaled-down topographic information via satellite. This can be used as a reliable tool for forest management activities, and their potential growth and reforestation. These technologies will be essential for the success of national, European and International efforts in forest conservation, such as those laid out in the European Forest MAP framework (particularly point 5, dedicated to forest information and monitoring). The efforts in the recent EU Green New Deal (European Parliament 2020), as well as in the 30x30 International Coalition – an initiative chaired by Costa Rica, France and the UK, for at least 30% of the land and sea to be protected by 2030 – which 50 countries have adhered to, including Portugal (High Ambition Coalition 2021).

In order to study and conserve ecological systems, it is paramount to be able to develop appropriate data collection and analysis technologies that allow for continuous, systematic and accurate information gathering about ecosystems. Currently, ecological mapping is done manually using satellite images by highly specialized experts in the field of ecology. This project aims to gather data from broad scale crowdsourcing for ecological mapping; in order to allow for automated predictive mapping through neural networks and artificial intelligence to map the forested lands, and urban spaces across Europe. Detailed data points can be achieved by using crowdsourcing through the development of a mobile application allowing users to visit various points on the map, enhanced by the use of gamification – which may be used for future research.

1.2 Objectives

The primary objective of this project is to develop an application that will allow end-users, whether this be students, researchers in this area (ecological studies), or regular citizens, to identify and travel to multiple locations that will be spread across a given geographical area within their city and surrounding areas. This will allow the users to contribute via easily inputting detailed information regarding terrestrial and aquatic habitats, which will be collected in a database – allowing for further data analysis. Ecological Mapping will also use gamification methods to engage users for citizen science data collection and location reviewing. This application should then be viable for use by educational institutions, namely from schools to universities, that can be identifiable as a collective, and potentially open for other institutions and individual data collection by members of the public.

Therefore, this dissertation has four main objectives:

- **Objective 1 –** design and implement a mobile application to ecologically map locations for the Android operating system. This will integrate map tools, and offer the ability to review locations. The user should be offered two methods of review, one being to review locations that are pre-determined by the owners of the application for ecological study, and the other being locations that can be input by the users;
- **Objective 2 –** design a web application to act as support for the mobile application to allow the owners of the application to upload (data points to be evaluated by the users) and download data (data points evaluated by the users);
- **Objective 3 –** design of the data model and implementation of the database for the data collected in the mobile application and uploaded by the web application;

- **Objective 4:** Test and validate the mobile and web application with expert users and in a use-case scenario.

1.3 Contribution

This project has contributed to LASIGE and the Faculty of Sciences of the University of Lisbon through the development of software components (the mobile application, web application and its online Database). The project was curated through an evaluation of the system by researchers and end-users, to be used by the cE3c group, along with potentially other research centres around the world.

The primary contribution was the creation of a mobile application, with the requirements, and objectives set above, with the aim of allowing users to contribute their knowledge and time to review ecological locations. The application is supported on all Android devices running from version 8 (API level 26) and above to the most recent one. Along with this contribution, we can include the creation of a web application that will supplement the mobile application, connected to a Firebase Realtime Database which will store all review data submitted by the users.

The final contribution, was the evaluation of the system. To do this, the application was tested with experts in order to evaluate the usability, and features of both applications. From these tests, it was concluded that the applications were well accepted by the users, and also that all the features implemented worked as originally planned. System evaluation should also be done through a use-case scenario by a user in Genoa, Italy, who due to the constraints related to COVID-19, could not further test the application.

1.4 Document Structure

This document is organized as follows:

- **Introduction** – work context, motivation, objectives, and contributions.
- **Literature Review** – presentation of literature research on published articles related to the methods approached in this project such as crowdsourcing and citizen science, along with methods of data collection for ecological and terrestrial mapping.
- **Mobile Application** – description of the features and requirements of the mobile application, resources, tools and methodologies used, along with details on the implementation of software functionalities including the integration of the map and

other features, data synchronization, web services, and expert testing and a case study of the application.

- **Web Application** – description of the features and requirements of the web application, resources, tools and methodologies used, web services and data synchronization.
- **Conclusions** – summary of the work accomplished, challenges, skills acquired, as well as suggestions and predictions on future work for the mobile and web applications.

Chapter 2

Literature Review

This chapter introduces existing concepts that are related to this project, primarily focusing on: crowdsourcing and the general theory behind it, gamification utilized on similar projects, and the current state on ecological and terrestrial mapping.

2.1 Crowdsourcing

Crowdsourcing is a recent area of research and practice which started to appear in literature around the year 2006, that emerges with Web 2.0 technologies. It relates to the use of collaborative participation between users that is mediated by technology, to solve problems and create products that are useful for an organization or person who requests it (Zhao & Zhu, 2012). Since this is a new field, there is disagreement about the specific definition of crowdsourcing, but here we will briefly discuss some common definitions and their use within Ecological Mapping.

Crowdsourcing can be understood as a method that is utilized by institutions, organizations and companies to essentially outsource tasks that has the goal to handle tasks that are difficult to perform without large human and financial resources (Brabham 2012). This view of crowdsourcing may be comparable to the concept of social computing, which relates to collaborative human work that is mediated through technology, to solve problems which both computer technology and humans without computer technology cannot yet adequately solve (Quinn and Bederson 2011). In this study, participants developed and collected computational data that will be used to generate a deep learning model which will be useful for research and conservation, a form of public participation, also considered citizen science (Wiggins and Crowston 2011).

According to Geiger and Schader (2014) and Prpić et al (2015), crowdsourcing systems are categorized into four separate categories depending on the characteristics of crowdsourced work: crowdrating, crowd creation, crowdprocessing, and crowd solving.

Crowdrating involves contributing a representative result such as surveyed opinions, crowd creation involves relying on a large number of diverse contributors to use different sets of skills to approach a problem and aggregate these into a single project. Crowd solving involves gathering insights on problems that benefit from diversity in alternative perspectives or specific skills. This project uses crowdprocessing, where Ecological Mapping will rely on the crowd to perform large quantities of homogenous tasks taken by different contributors – visiting the same locations, answering a standardized set of questions regarding the presence, typology and quantity of ecological characteristics. Crowdprocessing is utilized in the case of Ecological Mapping, to aid in the development of a learning algorithm, a large volume of individual contributions of data in the same locations are used to validate the information that is collected (Morschheuser, et al. 2017). Crowdsourcing relies on tasks taken upon by the community for little or no monetary compensation, hence motivation and incentives for participation are important in recent areas of research. The existing literature points to a combination of intrinsic and extrinsic motivation factors, as well as the importance of design elements (task, user interface, etc) which are suitable to the type and purpose of the activity of traveling to various points, and collecting data (Morschheuser, et al. 2017).

2.2 Gamification

The concept of gamification is relatively recent, appearing for the first time in the context of software engineering around 2008 in the Games Learning Society conference in 2008 (Walz and Deterding 2014), being defined as “the use of game design elements in non-game contexts” (Linehan, Kirman and Roche 2014). According to Linehan, Kirman and Roche (2014), the key aspect of gamification is that it entails “activities, which simultaneously stimulate and delight the participants, while also providing useful services to science, charities, and industry”, which most industries, businesses and applications are attempting to mimic in order to sell their products. Games have, since the early days of humans, been an intrinsic part of cognitive development, growth, building relationships, and developing key learning skills. Whereas in the modern era, with the introduction of game design elements into software (points, leader-boards, goals, challenges and time constraints), behavioural psychology allows for maximizing the motivation to do these tasks.

Morschheuser and others (2017) identified various design elements in gamification, which differ, according to the type of crowdsourcing method used. As previously identified, the application will make use of crowdprocessing, where the goal of gamification is to retain motivation and increase the number of contributions done by an individual. In their meta-analysis, these authors identified that the design elements that favour this engagement emphasize individuality (avatars, scores, progress tracking), competitiveness (leader-boards, levels of difficulty, missions) and less often involve immersion (storytelling, virtual environments). Although collaboration (teams) was not used in the literature of crowdprocessing applications – collaboration was mostly used in more labour intensive and creative crowdrating and crowdsolving tasks-, Ecological Mapping will use this method in order to fulfil the requirements set. The inclusion of collaborative design elements is due to the educational setting as well as the component of citizen science, as the application aims to encourage collaboration, community participation and involvement.

Considering that the mobile application will not be designed as a game itself; it will integrate gamification elements in order to promote a means for the public to get involved, contribute, and potentially discover knowledge and skills that they may be interested in. A sense of consistent feedback through game-like aspects will be the key focus when developing the application to make it more enticing for the user. Given that this application will be developed for scientific, public policy and conservation purposes, and requires public participation, it will be essential to address the key necessities that will promote this behaviour. In fact, an analysis of crowdsourcing studies which mobilize gamification principles (Morschheuser, et al. 2017) identified that these design elements are often used in crowdsource applications in the environmental, educational and geographic areas, where information-intensive data collection activities are combined with awareness of geospatial features and promoting conservationist behaviour. This can be explained by the dimension of motivation in human computation systems developed by Quinn and Bederson (2011); Crowdprocessing applied to local areas and ecological zones may promote altruism in users as they care for the conservation and improving of their environments. Positive reputation may be gained locally for their contributions as well as online through leader-boards. Enjoyment can be promoted through gamification mechanics in the applications. Even though the aim of Ecological Mapping is to enhance and contribute to investigation, through these applications, the students participating in this study may also learn and apply content that is relevant to their school curriculum.

Therefore, while the aim of Ecological Mapping is to develop and collect geospatial data that is useful for further research in urban green spaces, the schools participating may incorporate into their biology classes, using it as a real opportunity to develop citizen science, by doing inquiry-based scientific projects that develop participative learning, and may encourage students to engage in ecological conservation (Wiggins and Crowston 2011). In this way, this application has the potential to develop not only research, but also education, action and ecological conservation.

2.3 Ecological and Terrestrial Mapping

Ecological and terrestrial mapping aims to represent the natural organization of the landscape – by offering various levels of resolution, and helps provide an ecological basis for planning activities that can impact the environment. There are separate methods used to map ecological and terrestrial sites. The manual approach involves specialists looking at scaled down grids of geographic areas, that are generally created using satellite data, to understand and study the ecology of the zones that are being mapped. On the other hand, automated mapping uses only technology; and involves the input of algorithmic rules into a conceptual model to form relationships and mapping (MacMillan, Moon and Coupé 2007). Ecological Mapping aims to gather information through selected data points, and use these to map out key ecological areas for further research.

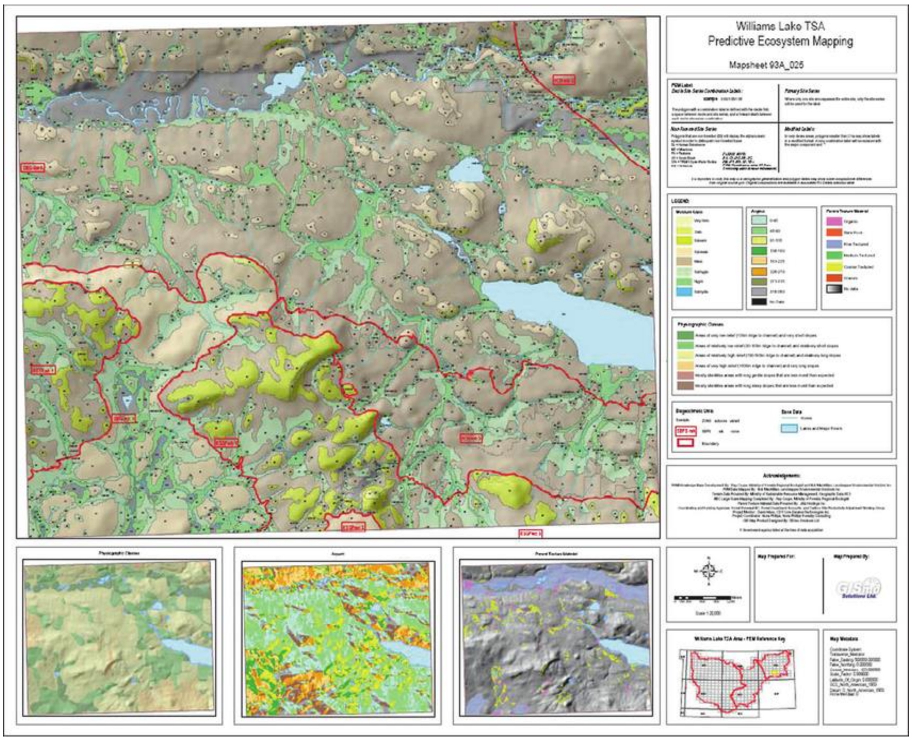

Figure 2.1. Illustration of a cartographically-enhanced 1:20'000 vector map[1]

In Figure 2.1 above, it is shown how ecological mapping takes places, where satellite imagery is developed into a vector map (in this case at a 1:20’000 scale) and the

1 (R.A. MacMillan, 2010)

information is manually input to classify different regions of the ecology. In order to study ecological areas, it is essential to understand the complex nature of these systems, as multiple spaciotemporal variables (time of year/day, climate, humidity, etc) in different regional levels (continent, country, local) impact processes related to plant and fauna (Fink, et al. 2014). It is therefore essential to consider these issues when monitoring environmental quality, especially when the goal is to identify target areas for conservation – spatial prioritization. This type of dense data is resource heavy, requiring time, many data points and temporal disparity, and citizen science has been mobilized as a solution to these issues. However, data collection and reporting tend to be sparse and occasional, and studies have shown that citizens tend to report using patterns of human activity – commuting pathways, points of interest, convenient times/dates.

The eBird (The Cornell Lab of Ornithology 2020) project, an ecological citizen science project developed by the Cornell Lab of Ornithology in 2002, aimed to provide data to estimate bird populations in the western hemisphere through citizen science, solved the problem of reliability by developing a specific spatiotemporal exploratory model called AdaSTEM. The citizens followed protocols with checklists and information about their location and time (Fink et al.,2014). eBird is a useful case study for the Ecological Mapping application, as it shares the *crowdprocessing* approach as well as collecting homogenized information (checklist, date-logging, location data) (Quinn and Bederson 2011). In the case of the eBird project, there is a need for the citizens to be specialized, whereas the application that will be developed in this project requires no specialization from the users, and is simply an added bonus – which can be resolved through scientific cross-referencing and can be partially solved by AdaSTEM (Adaptive Spatio-Temporal Exploratory Models).

Since Ecological Application does not aim to identify specific species, or migrations, but give data on the biodiversity in green urban areas, there are three advantages. Firstly, green areas will be targeted and identified in the application, which allows for data that is geospatially constant. Secondly, since the focus is in the area and not in a specific species, data on ecosystems will be obtained and it is not necessary to develop complex models to interpret data. Thirdly, since this application includes gamification principles, the users will be able to track their previous data collections. While at the same time, have access to information about priority areas that have not been adequately monitored, and incentives may be created for greater frequency and geospatial diversity of their data.

2.4 Summary

In this chapter, the most important aspects of Ecological Mapping, pertaining on how ecology is mapped at the moment using satellite imagery, theories on gamification and crowdsourcing are all discussed. By studying this research, we get a general understanding of how the application has to be designed, what it has to be designed around, and the technologies required for implementing this sort of application.

The following chapter presents the design and implementation of the ecological mapping application, including the mobile application, the requirements, and architecture, along with all the work done designing the UI of the application up to the current version of the application's interface.

Chapter 3

Mobile Application

This citizen science project consists of the development of both a mobile and web application for ecological mapping, where users of different levels of ecological proficiencies collect data and information, which will then help experts conduct field research of ecological points around the world.

In this chapter, we explain all the requirements, methods, design, architecture, and back-end of the mobile application. First, we present the requirements of the mobile application. Then the system and mobile application architecture is described, followed by the data model for the database. In the final section, we will present the user environment flow, including focus areas, wireframes and prototypes for the mobile application interface based on the diagram.

3.1 Application Requirements

For the mobile application, the following functional requirements (FR) were defined based on the objectives and needs of the project, alongside literature review on citizen science and gamification for ecological mapping. The user – belonging to a school, institution, or other – becomes attached to a domain that is created by the administrators of Ecological Mapping (specific for the project that the user will be a part of). The user should then review locations that are pre-determined by the administrators for the project, or chosen by themselves. The application also uses gamification components where the user gains points for each review that they make, which can be compared with the other users, and increase participation. Below we display the functional requirements (FR) for the Ecological Mapping application:

- **FR1** – allow users to make a review. The users should be allowed to make a localized review of their surroundings by answering a review form.

- **FR2** – pre-determined location reviews. There should be a list of pre-determined review locations that the user can click on to review. These pre-determined locations are key locations determined by experts to aid in the ecological mapping
- **FR3** – leaderboard system should be implemented so that users can compare their scores with other users of the application.
- **FR4** – allow users to select a domain in which they will connect. The domain is created by the administration of the application to categorize users into different databases, and get the reviews of each individual domain rather than all reviews.
- **FR5** – profile of individual users. All users should be able to create a profile when entering the application. This will contain no personal information about the user.

The application had a non-functional requirement in the project description that stated that it must be developed for both *Android* and *iOS*, however given the constraints during the project, it was decided to only develop on the *Android* operating system. In the table below (3.1), all requirements, design and implementation are detailed and organized according to their categories. These are divided into the tasks, and their descriptions which detail each element and what is expected to be accomplished within each.

Category	**Task**	**Description**
App Development	Interface Design	Design the user interface for all sections so that they can be easily implemented.
	User Registration Screen	Create a user registration screen in accordance to the necessary specifications, including: Username; Age; Level of Expertise (Choose between 3 levels); Domain.
	Pre-determined Point Locations	Button that a user can click to see all pre-determined points on the map.
	Data Evaluation Screen	Screen which will open once the user is sufficiently close to a data point – where they will have access to the information collection icon. Here they will be presented with the 4 review screens mentioned above in succession (Tree, Aquatic, Shrub, and Soil)
	New/Completed Marker Change	Change the colour of the marker when a user finishes evaluating a data point. (Red → Green) to show a sense of progress (reward fulfilment)

	Database integration readiness	Prepare the app to receive the API to connect information to the database with 2 separate steps: (1) Data Point Integration and (2) Data Send Integration
Database and API Connection	Creation, Integration, and Connection to Firebase	Creation of the database and connection to the application

Table 3.1. Development requirements

3.2 Application Design and Architecture

Several aspects of the design and architecture of the application will be determined through the requirements that were mentioned above. Figure 3.1 shows the main components: presentation manager; communication manager. The Presentation Manager, and the decision logic within it, controls the workflow within the application, allowing the user to move between different views that are presented (i.e., map, leaderboard, review and information view panels) in the user interface. In the section marked as Communication Manager, the application uses the mobile network to ensure that the Google web services are running (i.e. the map along with communication with the database, and location). The location manager ensures that orientation and GPS coordinates are accurate, and sends data to the content manager whenever a new review is generated, so that it can save reviews locally to send this information to the database once the user decides to complete a review. The data that is saved to the cache is then sent via the database manager to the database, containing all review information that is generated through the location manager. This macro level application architecture serves the purpose of understanding the various functions within the map method.

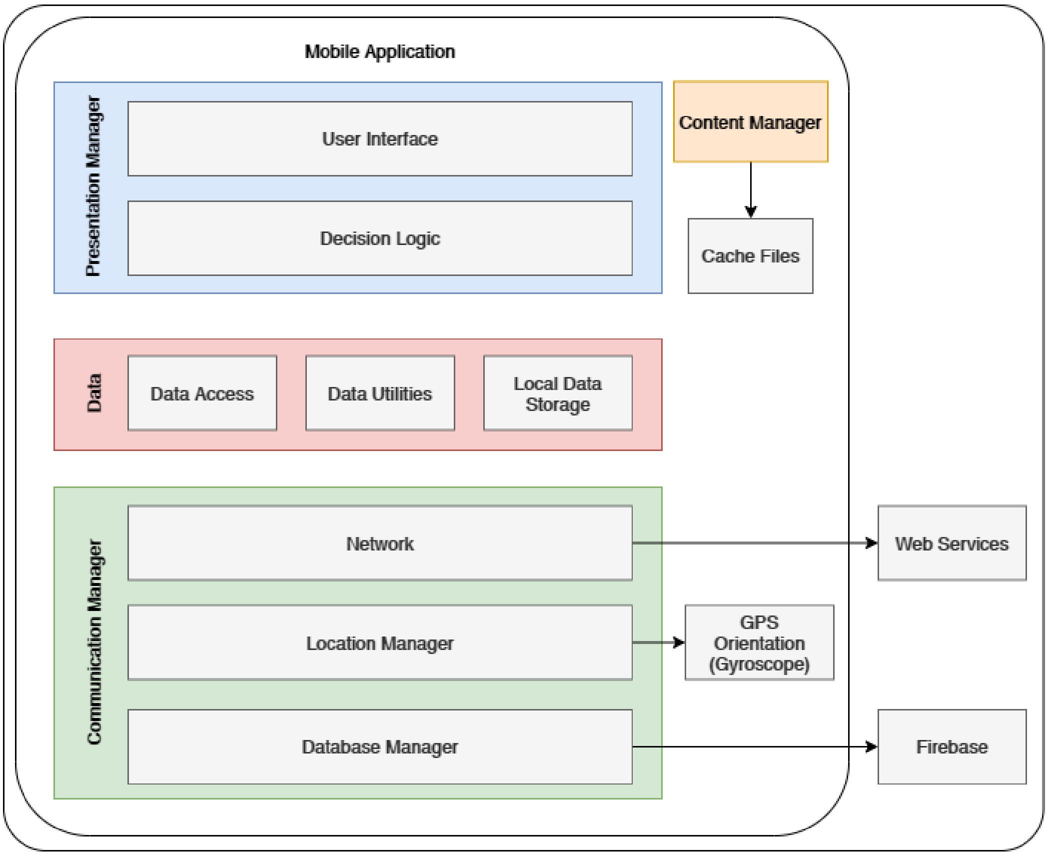

Figure 3.1 Mobile Macro Application Architecture

Workflow:

While designing the workflow of the application, it was decided that all users would receive on-boarding in the form of a tutorial to Ecological Mapping, followed by a registration process and access to a specific database. In this registration process, as shown below in Figure 3.2, the user defines their username, age, expertise and domain – where the username is a random pseudonym defined by the user, age is to specify their current age, expertise defines their level of knowledge in the field of ecology, and the domain is the database that they will connect to which is defined by the administrators of Ecological Mapping. Following the registration process, users will move onto the map view, where all the previously explained features would exist, and location reviews could be made. From here, the users would have multiple options for what to accomplish, whether they choose to review pre-determined locations, or generate their own locations.

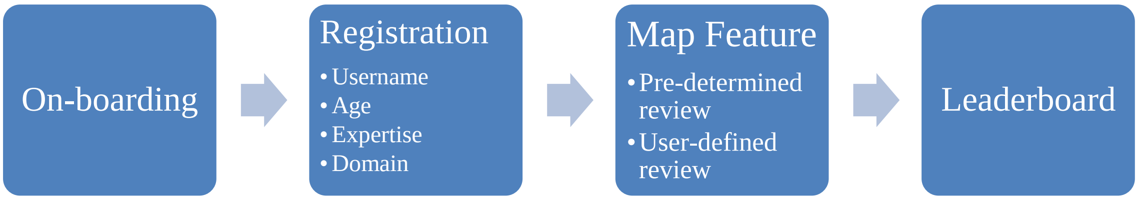

Figure 3.2. User workflow

To assure this workflow, the on-boarding needs to be done, so that all users can understand the primary features and requirements of the application. In the following sections, I will discuss the methods to design these workflow elements for the users.

3.2.1 Database and Back-end

During the initial stages of the project, many different database systems were discussed, including Amazon Web Services (AWS) – which makes other systems available, a back-end server that would be running SQL, or Firebase Realtime Database[2]. Due to the nature of the project, and the simplicity behind the data that was required to be sent to the database, along with easy integration with mobile application services – it was decided to proceed with the Firebase Realtime Database. The Firebase database is a cloud-hosted NoSQL database that allows for data storage and sync between users in real-time, without requiring any maintenance, and also allows to send Java Objects directly to the database in JSON format. The Firebase Realtime Database stores data as JSON objects – i.e. a JSON hierarchical tree. Any data added to the database, becomes a node within the existing JSON structure with its own associated key through the `push()` method, or set by the administrator of the database.

The database structure was developed through multiple iterations throughout the project as the project requirements altered and required structural adjustments. The initial database structure used the push() method from Firebase for user registration and identification (unique user ID), whereas future iterations required the user to provide a unique user ID or username as it is stated in the application. This data is then stored locally, as there is no password requirement for user creation, and thus the user is saved directly to each individual's device. When the user accesses the application, this local information is verified with the database, and all relevant data is taken from the database to allow the user to proceed from where they left off – namely all completed reviews, and their personal user score for the leaderboard. Along with this, the domain that was specified when the user registers their profile, is also saved locally – this starts

[2] https://Firebase.Google.com/docs/database

as default, and a user can specify a domain if one is provided to them when accessing the application for the first time.

Section	-1	0	1	2	3	4
Tree Cover	N/A	0%	<25%	25-50%	50-75%	75%+
Tree Type	N/A	None	No Evergreen	Few Evergreen	Mostly Evergreen	All Evergreen
Tree Height	N/A	None	All <6m	Mostly <6m	Mostly >6m	All >6m
Pond Area	N/A	0%	<25%	25-50%	50-75%	75%+
Pond Edge	N/A	No Pond	Natural Edge	Mostly Natural	Mostly Artificial	Artificial Edge
Pond Bottom	N/A	No Pond	Natural Bottom	Mostly Natural	Mostly Artificial	Artificial Bottom
Shrub Cover	N/A	None	<25%	25-50%	50-75%	75%+
Artificial Cover	N/A	0%	<25%	25-50%	50-75%	75%+
Grass Cover	N/A	0%	<25%	25-50%	50-75%	75%+
Bare Soil	N/A	0%	<25%	25-50%	50-75%	75%+
Irrigation	N/A	None	Low	Medium	High	Very High
Fertilization	N/A	None	Low	Medium	High	Very High

Table 3.2 Data structure for reviews

When a user completes a review, the application attempts to send the review object, detailed in (Figure 3.3 below and Table 3.2 above) directly to the database as is – reviews are detailed in section 3.3.5. Due to the nature of the real-time database, reviews can be sent directly without any form of editing required, and appear on the database as a JSON with a unique identifier, again using the `push()` method from Firebase. Since the object is sent directly to the database, all variables within the Java object need to be named in a way that they can be easily identifiable and in the order that is required when downloading the data. This is owing to the constraints of Firebase's methods of data acquisition, for the data to be downloaded as a .csv file with column names in an order that would be logical and easier to review. For the reviews, it was required to have certain variables stored in a way that retrieval was easier, namely two methods of timekeeping. A date (saved as `c_date` in the format of dd/mm/yyyy, HH:MM) and an epoch timestamp (saved as `z_timestamp`) facilitating the indexing of the reviews within the database, and allowing for sorting when required by date which can be seen in Figure 3.3 below.

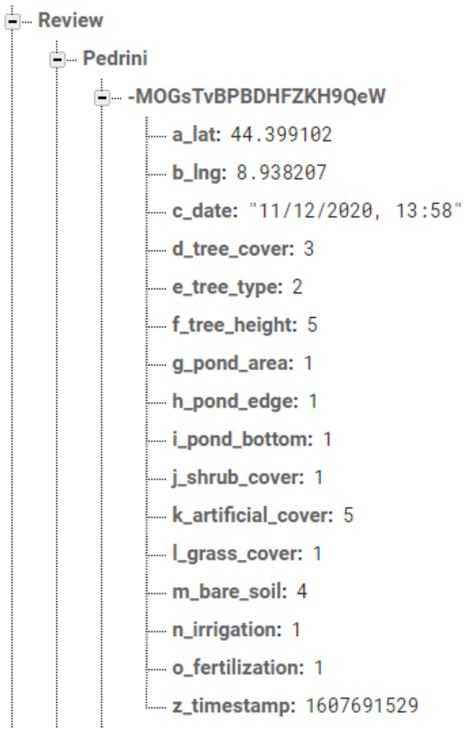

Figure 3.3 Review done of a point in database

3.3 Application Features

In this section, we will detail the main features of Ecological Mapping, starting from the profile registration, initial login and tutorial; the map features and reviews; user interface; location reviews in detail; leaderboard; and finally, the expert testing that took place.

3.3.1 Registration and Login

Early on in the definition of this project's requirements, it was decided that certain information regarding users should be registered in the database. This requirement does not aim to collect any personal data about the user, but rather to gather contextual knowledge about the reviews being done via the citizen science method, i.e., there can be users who have a higher level of expertise than others. Additionally, given the potential mass audiences (although at an initial stage, this will be limited to specific groups), when the user accesses the application for the first time, they must also be presented with information about the application (what the project is about) and how to use it.

The registration process was defined as a way for users to create a persona profile, and for Ecological Mapping to obtain non-personal (not identifying) information about the user. Allowing for future data validation and analysis to take into account these contextual variables, whether it be in terms of prioritising input data validation according to the level of expertise, or understanding how different publics may approach the same geolocation made by different users.

Table 3.3 lists the user information that was planned to be available when the application was first developed, requesting the age of the user, along with a level of expertise where the user would select from 3 distinct options (Beginner, Enthusiast and Expert) and level of schooling, similarly with 3 options (High-school, Undergraduate and Masters). This information would be used to understand the level of accuracy of the reviewed data, comparing the information gathered by citizens to those done by experts, and give a clearer insight if these methods of citizen science can be used to gather accurate geological data.

Information	**Interface Input Type**
Age	Integer
Expertise	Radio Button
Schooling	Radio Button

Table 3.3. Original plan for user information and registration

This was implemented in the prototype that was tested by experts (members of the cE3c team) to better understand the workflow of the registration process, which led to the following alterations:

Username: At the start of the project, it was defined that users would not define a username upon registration and would therefore only be attributed an identifier through Firebase. This was decided in order to ensure anonymity, since the usernames that are chosen may not be pseudonyms, but alterations of real names, which can be identifying, and not respect regulations regarding user privacy given that the users would not be accepting a GDPR consent form. However, as the project progressed, and particularly after the implementation of the leaderboard element, we found that the lack of a username was a detriment to the gamification elements which will be explained in the testing section (3.7). To prevent the need of added security, and simplify the process of registration, it was decided that users would not need to authenticate themselves, but rather once a user is created, that user is saved both on the database and locally (to the device) using a generated push key unique to themselves – this way no other user can have access to their account. This would also mean, that if a user lost their mobile device, they would have no way of recovering their account, and would have to create a new user. It was also decided, that no two users could have the same username, thus offering a more personalized experience. The information the user provided when registering their user can be seen in Table 3.2 above. Given the feedback, the decision was made to remove the schooling field, due to users feeling uncomfortable providing this data. Also the mobile application could potentially see its way in schools or other programmes, where all users would either have the same level of schooling, or simply no level of schooling.

Domains: A new registration process was implemented where we included for users to select the database they were connecting to, allowing the research team to condense the reviews made to certain specific research groups (providing the application to schools, universities, etc.). If users choose to omit the domain, they will enter a domain called "default" – allowing all users access to the application, even if a domain is not specified.

Table 3.4 shows the new information that users provide when registering themselves to the application, taking into account the three elements discussed above.

Information	**Interface Input Type**
Username	String
Age	Integer
Expertise	Radio Buttons
Domain	String

Table 3.4. Finalized plan for user information and registration

As aforementioned, when registering to a domain, each user would be assigned to a specific database, where all completed reviews of their geological locations would be saved. Below (Figure 3.4) we can see the final version of the welcome/registration view that was developed for the application, with the information in Table 3.4.

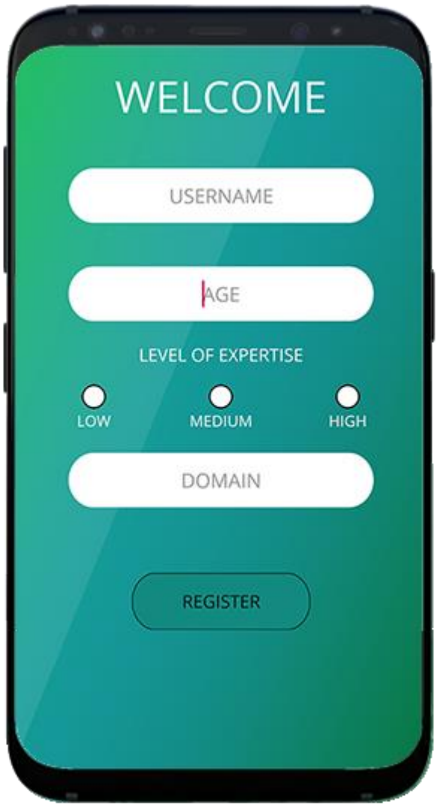

Figure 3.4. Final registration view

3.3.2 Tutorial

Many mobile applications, particularly games, tend to include an on-boarding method to ensure that the users can easily understand the mechanics and workflow required to achieve specified end-goals. In a similar manner, it was decided to add an on-boarding for the application that would explain all the functions, what the application is about – particularly given that this application's use for scientific purposes – and how the workflow ought to be. This tutorial would be visible to all users when they start-up the application for the first time, and could be accessed again through the side menu panel once the registration process is complete.

This on-boarding was made to include all the primary features of the application, including explaining how the user would review geographical locations around the world, along with the use of each of the features within the application. This is particularly relevant given that the primary feature of the application is to solicit users' collaboration in submitting reviews, and in order to do this, the users must get a good understanding of the process as well as the required ecological information. Figure 3.5 illustrates the five-step process of the tutorial. In the tutorial design, we aimed to build upon the elements of the application, with a more detailed last step that integrated the information introduced in the previous steps (particularly steps 2 to 4):

1) Opening Screen with a brief description of the Ecological Mapping Application: Introducing the aims of the application, as well as the integration of technologically obtained data (via satellite) and user collaboration (via reviews);

2) Review Elements: Introduction of the steps and user inputted data, namely travelling to an ecological site and reviewing required elements;

3) Locations and Leadership Board: Detailing the option of using pre-selected geographic points or generating a new geographic location for reviewing, and introducing the Leadership Board element of the application;

4) Location data and Permissions: Requests the permission to collect location data and explicit mention that no other information will be collected;

5) Process of Reviewing: The detailed process is explained, by describing how a user should aim to review a location once they either reach it, or choose to make their own – where they should review the location based a 10m radius around them as shown in the figure. This allows for an accurate description of the ecological condition of the location. – which will be explained further in Section 3.3.3.

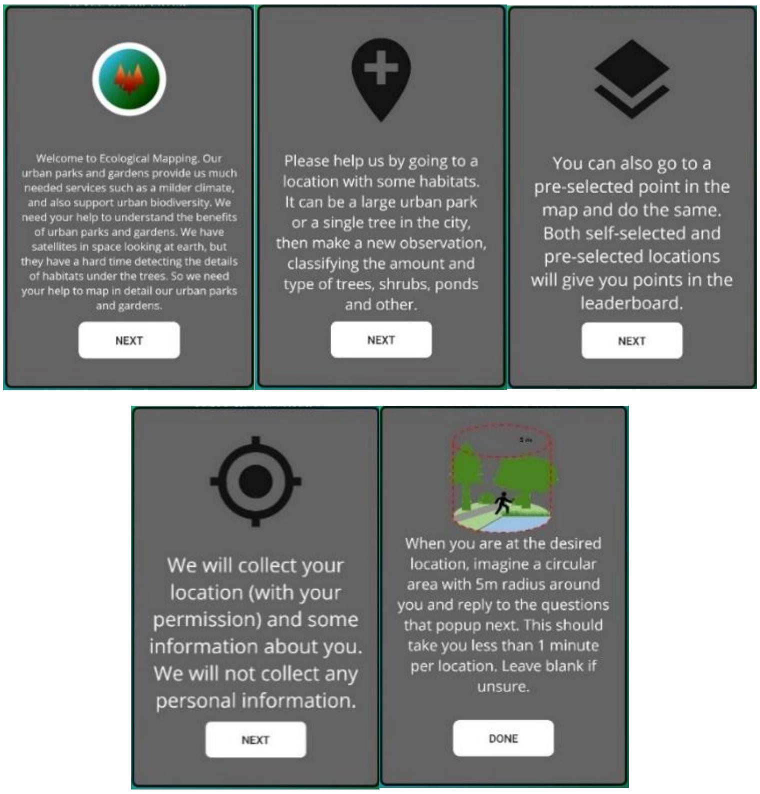

Figure 3.5 Tutorial Panels 1-5

3.3.3 Map Features and Reviews

This section will discuss the map features, the format that was used, along with all the features that are available on the user interface, how the location tracker works, including distance to location. Also discussed here, is the method for users to review a location – where they have two options on whether to review a location that is determined by the administrators of Ecological Mapping, or by being at a location and clicking on the user interface to start a review at their location.

Map Features and GPS

For the map, the Google Maps Platform[3] was chosen, due to the following reasons; the API allows us to embed the Google Map directly to the application, retrieve information from Google Maps, and is also free to use. Considering we are developing an application for *Android* systems, the *Maps SDK for Android* [4] was used.

Since this application was developed in Java, we must configure the initial map state, along with the following required features;

- Disabling the MyLocationButton (default Google Maps button that centres to the user's current location), which was replaced via a custom button, that can be relocated
- Disabling the compass (orientation), as this is not a requirement for the application,
- Setting the default zoom level to 17 (from the default of 13), allowing for a better view of the surrounding area. This is so that, when the user clicks to show the pre-determined locations, there is a greater likelihood of them seeing one, i.e. to potentially reduce the number of interactions before having access to the key features.

In terms of the types of topographic data in the map, Google allows for several types to be chosen, ranging from the following:

- **Normal**: Typical road map. Shows roads, some features built by humans, and important natural features such as rivers. Road and feature labels are also visible.
- **Hybrid**: Satellite photograph data with road maps added. Road and feature labels are also visible.
- **Satellite**: Satellite photograph data. Road and feature labels are not visible.

[3] https://cloud.Google.com/maps-platform

[4] https://developers.Google.com/maps/documentation/Android-sdk/overview

- **Terrain**: Geologic topographic data, which includes colours, contour lines and labels, and perspective shading. Some roads and labels are also visible.
- **None**: No tiles. The map is rendered as an empty grid with no tiles loaded.

Each of the above map types allow for different sorts of implementations, where "None" allows for a custom map to be loaded on top of the empty grid. Given the requirements of this application, the default map was chosen, in order to include both natural and man-made features and facilitate the user's interpretation of the geolocation in the points. Although it was discussed whether satellite mapping should be used, ultimately it was found that in urban areas, the additional detail of the map made it so the natural features -which are to be reviewed- are less visible.

For Ecological Mapping to be able to function, we need to use the user's geographical location, so they may move around the map and review locations as they please – for this, the use of the mobile's GPS is required, and consent is given when the application is launched. Although users may use the application in offline mode to navigate around the map, they will need to have internet access when starting up the application – and all reviews that are done while the application is not connected to the internet will be stored in cache, and sent to the database once the application has regained online access. This allows users to freely navigate the application without having to rely on network charges, or mobile data usage. In order to use the GPS on *Android* devices, we must use the location provider client.

```
FusedLocationProviderClient.getLastLocation()
```

This works as the entry point for interacting with the location provider, and allows the Ecological Mapping application to return the user's best most recent location available, thus allowing for cached locations to appear in case the user has a bad satellite signal in their location. Attempting to always call the method `getCurrentLocation` attempts to return a single current location, which may cause issues when loading up the application if the user does not have good access to location services.

Location Markers

The main feature of the Ecological Mapping application is to review ecological points. In order to do this, since the base of Google Maps is being used for the map view, we considered it intuitive for the users to have location markers to mark locations for review and to identify that have been reviewed. It was also decided that users should be able to see all the markers regardless of their distance to them, to be better able to understand the number of pre-determined points (discussed further) they can review in different areas of the world, and potentially plan routes. As can be seen below (Table 3.5), a colour scheme was chosen in order to provide users with information regarding the availability and selection of markers.

	The base marker type, and colour (red) were used for the locations that have yet to be reviewed by the user.
	When the user selects a marker, it will change colour (orange), and information at the top left corner of the screen will indicate the distance between the user's current location and the location. When the user has reached the area -or, if the application is in offline mode, the user indicates the location has been reached-, the application will enable a review to be entered.
	Locations that have already been reviewed will change their colour (green). This uses gamification methods which aid in positive reinforcement and help retain motivation by seeing their own progression directly visible to them on the map.

Table 3.5. Location Markers

The location markers will be split into two main types – these being the pre-determined locations and user-determined locations. Both of these types of reviews offer different user experiences, where the former allows for the researchers to control the specific locations that need reviewing, and gives the user a set goal to accomplish, the latter is not controlled – i.e., users can be anywhere and review their location. Both of these methods of reviewing locations will be discussed ahead.

Pre-determined Locations

As aforementioned, pre-determined locations are set by ecological researchers directly into the database which can be accessed by Ecological Mapping users. The decision to have pre-determined locations was to allow for the researchers to create various ecological points around the world to mobilize citizen science to research these areas, by requesting users to review these locations. These points also serve the purpose of gamification, allowing for the users to have a tangible goal while researching, as the user-defined locations do not provide any incentive to do so.

These pre-determined locations are fed into the database via the web application which will be discussed in the next chapter, and are accessible to all Ecological Mapping users via the interface. By default, these map locations will not be shown, and the user will enter a *free-roam* mode, where they can explore the application, and all the interface options available to them – in this mode, they can create their own reviews. Once they access the user interface, they can enable the pre-determined points, and see all the global points set up by the researchers, and move towards these to review them.

User-defined Locations

It was decided in the application requirements that users who do not wish to contribute to the pre-determined locations, or if ecological locations in their area have not been identified by researchers, they may still contribute to the research by reviewing locations of their choosing. To be able to review a location, users need to simply open the application, and begin a review, which will open the review interface and allow them to review their surroundings.

3.3.4 User Interface

In this section, we will discuss the decisions made behind the user interface (UI), how they came to be, and why. For the main section of the application, as mentioned previously, the Google Maps API would be used for the main map feature of Ecological Mapping – also as mentioned, the default location and compass buttons were disabled so that we could create and have the button design in the method that would coincide with the other buttons in the application.

In the Figure 3.6 below, we can see all the elements and their placement on the screen. On the right side of the screen, we have our buttons – these allow for navigation within the application, from top to bottom: 1. Current Location, 2. Leaderboard, 3. Show/Hide Pre-Determined Locations, and 4. Create New Review. The decision to have the buttons on the right side of the screen and having 2 buttons at the top and 2 towards the bottom of the screen was to follow the way Google Maps originally has their buttons, all being placed on the right side of the screen – but have buttons 3 and 4 towards the bottom as they are easier to access when holding the phone with the right hand. At the moment, there is no inverted interface for left-handed people, although this can be implemented in the future easily – nonetheless, the features are easily accessible.

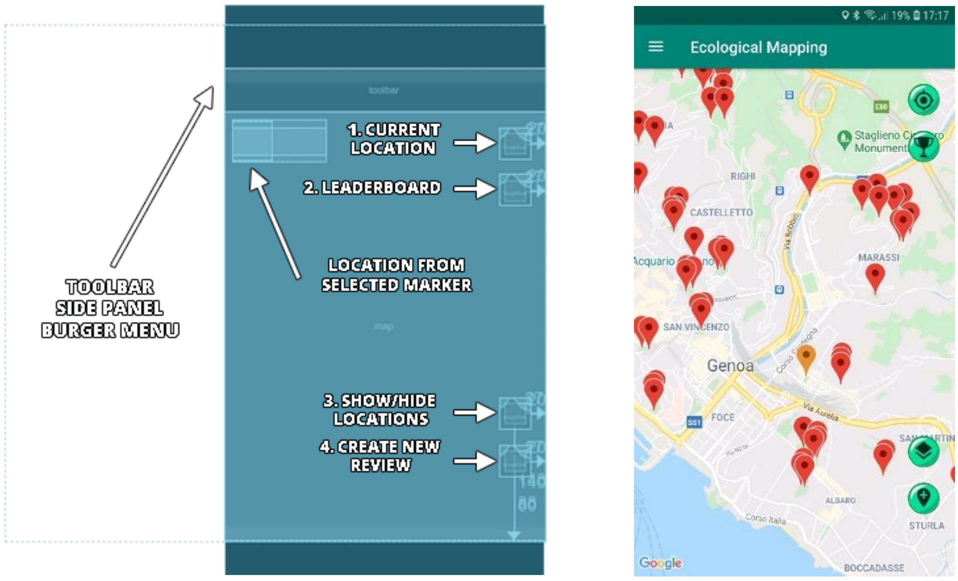

Figure 3.6. Map view blueprint and implementation

The elements displayed above (Figure 3.6) will be detailed as follows:

Toolbar Side Panel Burger Menu: It was determined that there would be a need to have a menu to access certain features, such as the tutorial that was shown when starting up the application (as people may have forgotten how to use the application), along with information about the project itself in an "About" section, and finally the credits. This side panel, defined as a Navigation View, as shown in Figure 3.6 by the dotted line, was set as a side panel which the user can swipe on the left side of their screen to access, or simply click on the "hamburger menu" button on the toolbar section of the application. It was decided to have 2 options to load up the menu, although one not being obvious as it allows for ease of access, and better accessibility. The Navigation View, uses the java method Switch to navigate the different sections of the view, where the user can click on each of the items in the panel to open the designated view – using the switch/case method for this is the best method for a simple navigation panel as we have here. Clicking outside of the navigation panel automatically closes the navigation view allowing for a seamless transition between opening and closing the panel.

Location from Selected Marker: Another requirement was to be able to see how far the user is from their selected pre-determined location marker – as the user needs to be within 5m of the location marker to be able to start a review of that specified location. The methods on how this was implemented will be detailed further in the Location Reviews section. The distance between the user's current location and the location of the marker are shown at the top left of the screen, being the furthest distance from the user's hand – this is not clickable and exists merely to show distance. It also replaces the marker colour from red to orange to state that this is the location they are meant to be traveling to.

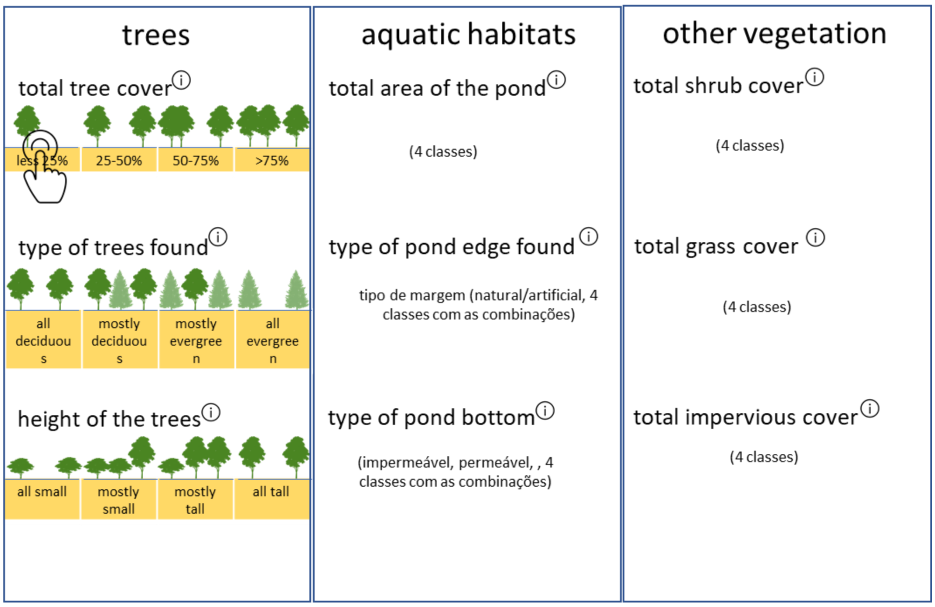

Figure 3.7. Initial review blueprints

Location Review Panels: Finally, the view that makes the review had many designs before it was finalized. The initial design blueprint, before being added to the application, is visible in Figure 3.7 above. This initial design would be the base for what would be in the application – which contained fewer components to the review than the final version. The elements are placed in separate views that distinguish each portion of the review, containing Trees, Aquatic, Area and Soil review panels.

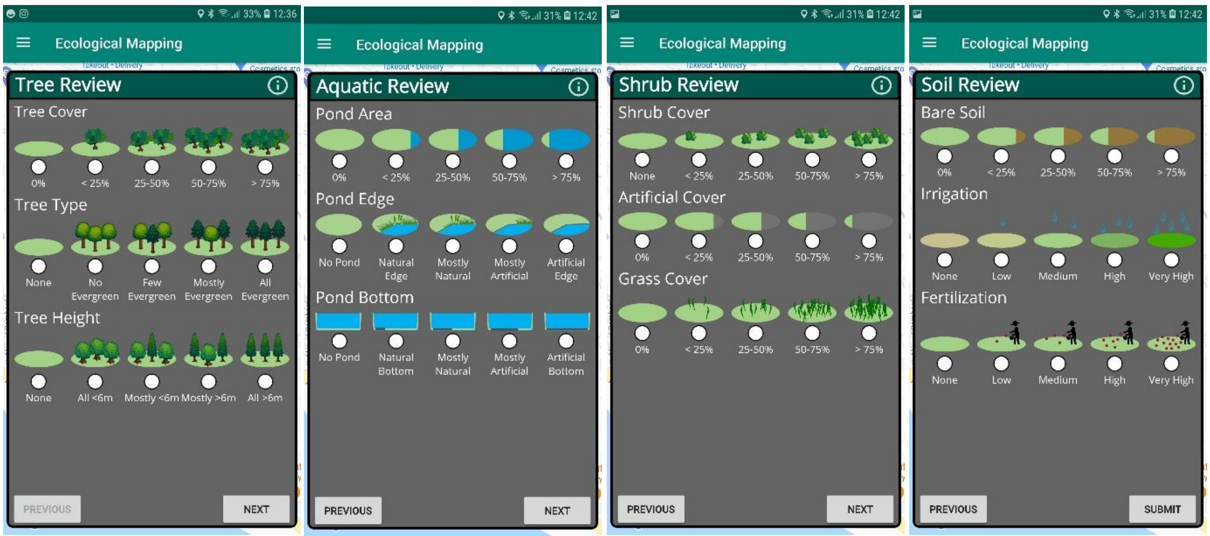

Figure 3.8 Final review panels

In the following section, we will detail these elements, and the final version of the location review panels can be seen in Figure 3.8 above.

3.3.5 Location Reviews

As mentioned in the previous sections, the location reviews are the locations (either pre-determined or user-generated) that the user accesses in order to characterize the ecological surroundings. These can be pre-determined locations set by the researchers through the web application, and can be viewed by all users of the application, regardless of which domain they are connected to. Once a user selects a location that they wish to travel to, they will then have to move to the specified location, and once within 5m of the location, the review process will automatically begin – if they are standing on the location already, the application simply checks whether they are within 5m and starts if this requirement is met, otherwise the current distance to target view will appear on the top left corner of the device to show how far they are from the point. As this application is not meant to be used for navigation (i.e., to show how to reach said location), the users must themselves move towards it without any direction prompts. This was implemented via the `distanceTo` method of the Location class, where two locations are compared – the user location, and the marker – multiple methods can be used to compare the distance from one marker to another, such as `distanceBetween`, also part of the Location class that receives a starting/ending latitude and longitude and returns a float. The `distanceTo` method made more sense to use in this case, as we already had the location marker set as a `LatLng`, using the `LatLng` class, and providing this to the Location class would make more sense than to split the location into its separate components (as Lat and Lng floats). In Figure 3.9 below, this `distanceBetween` is shown on the top left corner of the application screen.

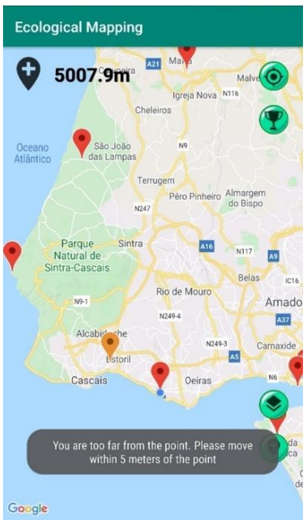

Figure 3.9. Distance to pre-determined location

Once at the point, users will automatically enter the review panel, which will allow them to submit a form, containing various radio buttons each corresponding to a value set in the fashion of an ordinal scale – these values range from -1 to 4, -1 being the default value representing an unanswered section (this can be due to the user not knowing the information or none of the other values applying), 0 being none (i.e. the lowest value), and 4 being the highest value. The reason it was chosen to have an ordinal scale, is due to the ease of comparison between variables, and works well with grouping for AI models to be able to work with the values. These are not considered simply unordered variables, as having the order makes it easier for the user to be able to answer the form. The structure of the input data is shown in Table 3.2 in the database section above, and in Figure 3.10, it is shown how it was integrated in the User Interface of the Location Review Window.

Figure 3.10. Location review panels

On the other hand, users can also choose to review the ecological surroundings of any point in the world by simply clicking on the "Start Review" button – this will create a new marker on the user's location and once reviewed, gets sent to the database. The user can create multiple reviews of the same location, as Ecological Mapping does not check for distance to other nearest markers – this was done as checking all markers nearby to understand whether a review has been done in the same area before, continuously, could potentially cost more in terms of the number of requests sent to the database. It was also decided to allow for users to review the same location multiple times as a user may choose to review a location at different times of the year, thus providing useful information.

3.3.6 Leaderboard

Gamification was a central part of the design element of the Ecological Mapping application. It was decided that it would be important to implement a Leaderboard system, where users could compare themselves to all the other users – this being especially important if the application were to be used for select groups such as schools (each with their own domain), where the users could compare against each other how many points they had reviewed, allowing for intragroup comparison. As mentioned in the Profile creation section (3.2.1), at the beginning of the project, it was decided that users wouldn't have usernames, and for the leaderboard, it would show your score as "You" and the other users would simply show as "Another User". However, for gamification purposes, and in order to allow for personalization, it was decided that users could choose a username for themselves, thus improving the leaderboard and user engagement within it. As seen below (in Figure 3.11), if the user is not within the top five reviewers, they will not appear on the leaderboard – this was altered later to always show the user, even if they are not among the top reviewers.

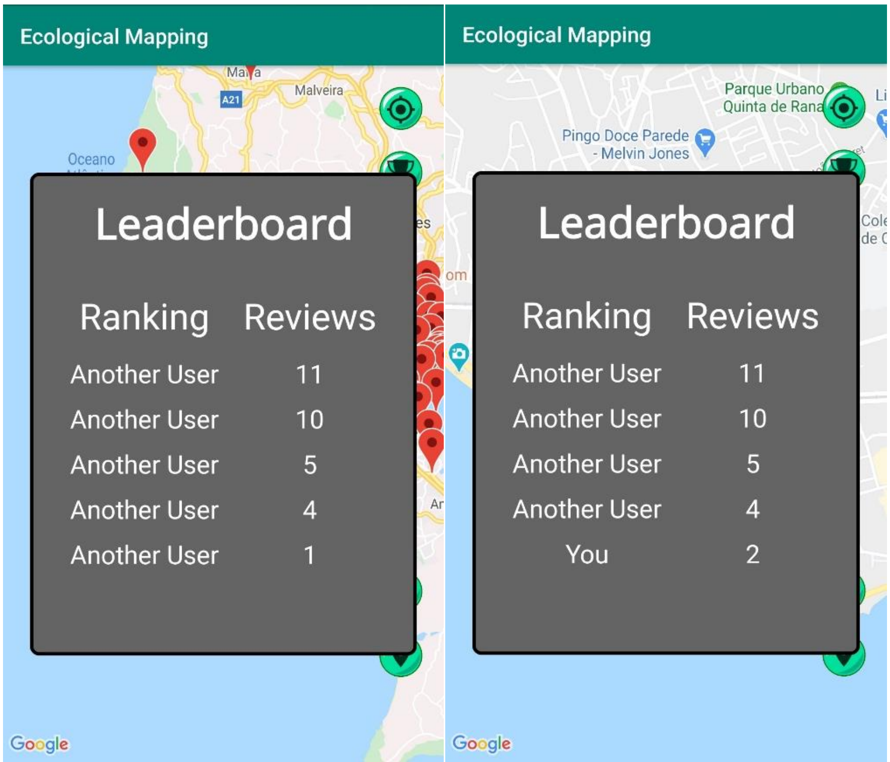

Figure 3.11 Old Leaderboard format showing "Another User"

Once usernames were added, these appeared on the leaderboard as well, "You" was altered to simply show the username of the user using the application at all times – allowing for the users to find their score and ranking more easily. The number of reviews done by the user are saved (locally and in the database) as a `userScore`. To prevent discrepancies, when the user loads up the application, it downloads the latest score from the database. All users start with a `userScore` of 0, and each review increases this value by 1 – similarly to the reviews, if the user chooses to use the application in “offline” mode, their score will be saved to the cache, and updated in the database, once the user is online. The rest of the users in the leaderboard, are gathered using the Firebase `ChildEventListener` method with filtering using `orderByChild` via database indexing, and limiting these to the top 5 with `limitToLast(5)`. These values are saved in the database under each domain and specific user with the key “score” as shown in Figure 3.12.

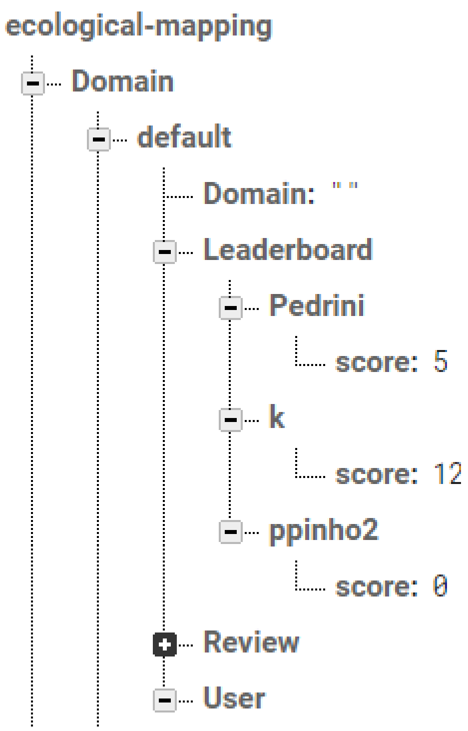

Figure 3.12. Leaderboard database scores

3.4 Expert Testing

To validate the characteristics of the application, and to see if the requirements were met, a prototype of the application Ecological Mapping was tested. We started by having multiple experts in the field of ecology, evolution and environmental changes, from the cE3c team. These experts, then tested the application and collected feedback in order to assess improvements to the application (what was required from the application to make it more intuitive, easier to use) and provide better information for the experts.

Given the constraints during the development of the application, namely COVID-19, this testing could not be carried out in-person and in-loco, but rather via online communication, that altered the initially planned tests methods, which involved field testing multiple data points, sample collection, data download and manipulation, among other tests.

3.4.1 Objectives

The primary objectives of this expert testing were to meet certain objectives:

- Is the workflow of the application intuitive and logical to follow?
- Is the review workflow, and the images presented easy to visualize and understand?
- Is the downloaded data presented in a manner that is useful to the experts?
- Get a general understanding of the usability of the application.

3.4.2 Tasks

The participants were given the application with a brief explanation on what Ecological Mapping was meant to be used for, and how it would work. In this introduction, they were presented with the application and some simple tasks, which were:

1. Register a profile on Ecological Mapping.

2. Access the map and its features – attempt to understand the buttons and what they did.

3. Make a local review of their surroundings.

4. Make a review of a pre-determined point.

Given that this testing took place over online communications rather than in the field, outdoors, there were limitations on **T4**, where the users could not access a location point. There were attempts to create points near to the participants, and thus only some participants were able to complete this task. This list of tasks was not provided to the users, but rather spoken verbally over a meeting and through online communication, namely e-mail.

5. Does the format of the downloaded data match the requirement of the experts?

This final task **T5**, was not presented to all the participants, but rather to the researcher who would be using the application, and distributing the project to other teams.

3.4.1 Feedback

During the testing, there were plenty of inquiries regarding several features of the application. Namely, how the participants could represent themselves through a username (pseudonym), certain usability features which caused minor visual bugs (the map still moving while in a review screen, the text not fitting correctly on smaller screen phones), along with other functional bugs (certain features not working as intended). Also, different gamification methods that could be applied (such as having double the score for a review on a pre-determined location, versus a personal review). During this period, these experts suggested the introduction of domains and usernames for personalization, and data analysis.

Adding to this, when submitting the review data, the formatting of the data that was necessary to be able to review and manipulate, was altered as shown in Figure 3.11. Some of the improvements mentioned above, regarding the inclusion of usernames, adding the user themselves to the leaderboard, and the addition of extra features that required reviewing were all part of this feedback that was given once the application was tested in the field. Due to COVID-19 restrictions, field testing could not be as extensive as what was planned in the early stages of development, thus causing a delay in the project itself.

As mentioned in Section 3.4, soil, irrigation and fertilization were not aspects that were initially included in the project requirements, but were added in later phases of development after receiving feedback from the participants, where the information that was given was not enough to understand the ecology of the area. The experts also requested if one point could have multiple reviews, in different seasons, – this was not considered for the pre-determined locations, but still available for user-defined reviews. This decision was made, as the users would not be able to comprehend why the point that they reviewed wasn't being marked as complete on the map (which would go against gamification methods). In future iterations of Ecological Mapping, it could be possible to set a minimum time requirement between one review and the next one of the same points if this feature becomes necessary. This would allow users to submit reviews of the same location during multiple time periods and providing more accurate information throughout different times of the year. The feedback given allowed us to weed out multiple bugs and push the application towards being tested by users that would be using the application outside of testing purposes.

Ecological Mapping was also meant to be evaluated in a use-case scenario by an Erasmus student in Genoa, Italy, who due to the constraints related to COVID-19, could not further test the application to date.

3.5 Summary

This chapter presented the requirements, architecture, resources, and methods used during the development of the project. We started by presenting the functional requirements of the application, followed by the design and architecture. Next the registration features were discussed – including the changes made throughout the duration of the project, – followed by the map and all of its' features. Finally, the location reviews were presented, along with all the features that encompassed it, and the leaderboard system and how it functions. The API's, including how the information was downloaded and send to the database was presented to explain how communication is done with the host database for the applications' primary features. In the next chapter, we will discuss the web application, the requirements, and the features that were necessary for it.

Chapter 4

Web Application

The web application component for Ecological Mapping is designed to access the database, download and upload data. Experts can use the web application to upload data points, download reviews, and create new domains for their users to be able to access. In this chapter, we present the requirements, methods, and design of the web application. First, we present the requirements and features, followed by the back-end.

4.1 Web Application Requirements

For the web application, we defined FR’s based on the objective and needs of the project and what was required of the web application.

- FR1 – allow experts to upload data. The users of the website, should be able to easily upload point data for the mobile users to be able to reach and create reviews.
- FR2 – allow experts to download data. Users of the website should also be able to download all review data in a format that is analysable with the least amount of effort.
- FR3 – allow experts to create new domains. The experts should be able to create new domains for the users to access when using the application for the first time – thus allowing focus groups to be created and the application to be used in multiple scenarios. In this page, the experts should also be able to view what domains currently exist.

It is also required for the website to be able to run on all browsers, connect to the database, and be hosted on a platform for easy access by the project owners. For this, we will be using HTML for the base design of the website along with CSS for the design elements, the web application will also use JavaScript for connection to the database and to run any required scripts. Another feature that was added, although it was not a part of the requirements, was to develop an Adaptive Website Design via CSS, allowing for experts to access the Web Application from any device.

4.2 Features

The primary features of the application, as mentioned in the requirements above, will be to allow the owners of Ecological Mapping to control certain aspects of the application, and database via the web application. The main page of the Web Application (see Figure 4.1) is structured in three main parts: the logo; the menu screen; and a main section. On the landing page, a slide scrolling image (SSI – visible in Figure 4.1) view was integrated, with four images illustrating Ecological Mapping: SSI 1 shows the Location Review Window, SSI 2 shows the Registration Screen, SSI 3 is the Map interface, and SSI 4 shows the Menu.

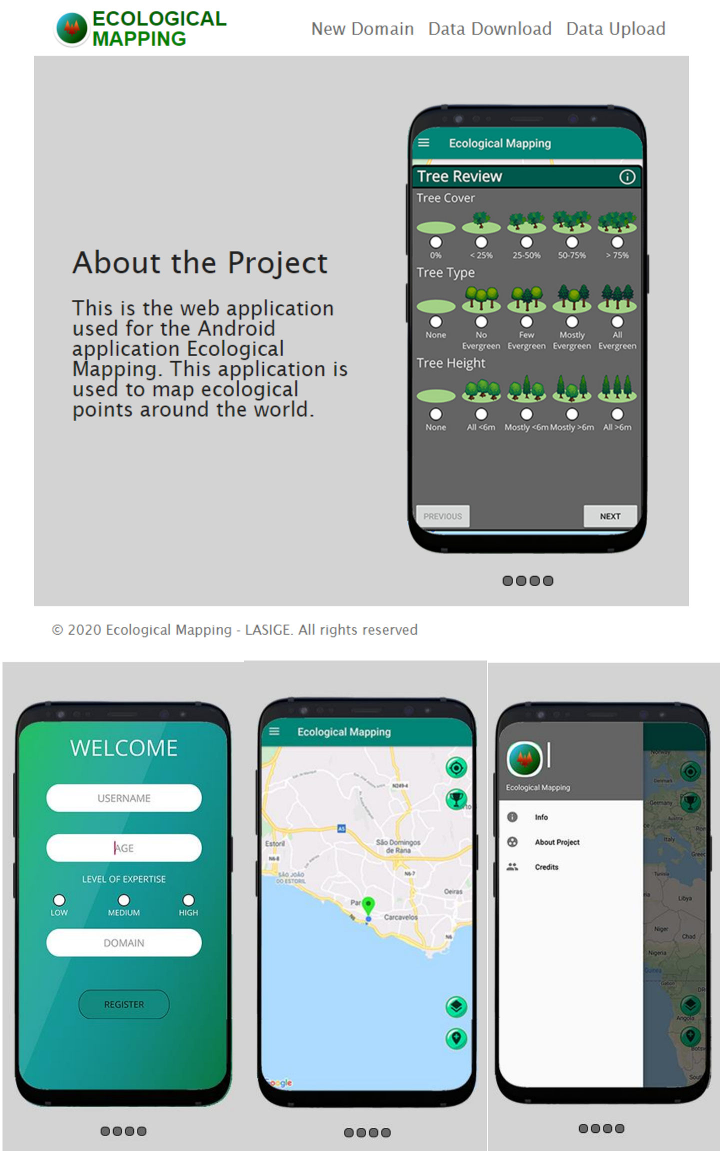

Figure 4.1 Web application landing page and SSI 1-4

4.2.1 Creating Domains

An important aspect of the web application is, firstly to be able to create new domains to allow users to access the mobile application. When a user begins the registration process, as mentioned in the previous chapter, they will be asked to provide a username, their age, information regarding their level of expertise in the subject of ecological mapping, and a domain – this domain gives them access to a specific database, each with its own set of users and thus a leaderboard. To access the mobile application, users are asked to specify a domain, although this is not a requirement, as leaving the field blank sends users to the default database, labelled "default" (mentioned in Chapter 3.2.1).

On the web application for Ecological Mapping, it was also required to show what domains currently exist, and not allow the owners of the application to create the same one again as this could potentially wipe the existing domain to create a fresh one. To prevent this, two separate methods were developed – the first being a soft check, where all current domains are displayed on the web application in the form of a table as shown in Figure 4.2. Meanwhile the second being a hard check where if the user attempts to use the same name as an existing domain, it is rejected directly by the application, and the user gets an error displayed by the web page, which was done via a the `includes()` method of the Array class. If the user attempts to create a domain that does not exist, they are greeted with a confirmation message, along with the table being updated with the latest domain in real-time.

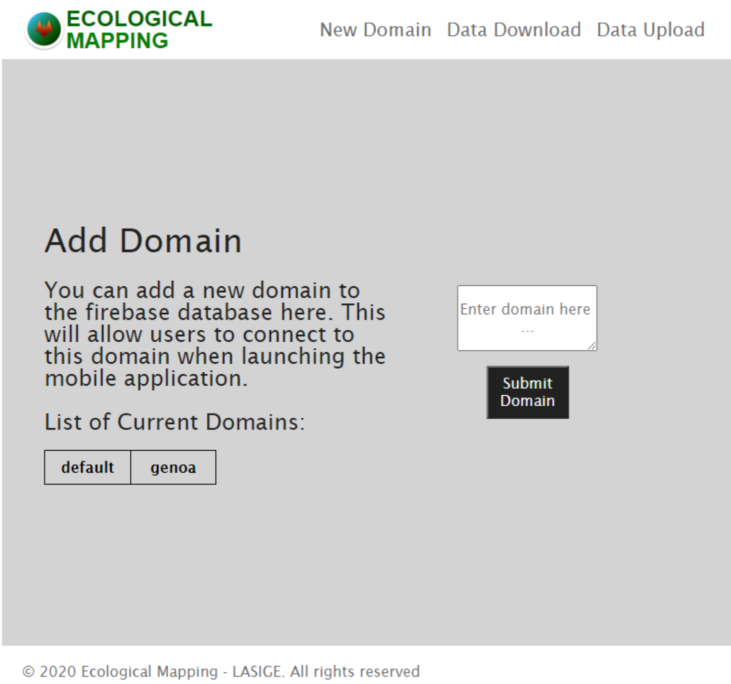

Figure 4.2. List of current domains - displayed on web page

4.2.2 Data Upload

An important step in ensuring that users can access the list of pre-determined points, these points need to be uploaded, and there are several methods of uploading this data. Given that the point data needs to be uploaded to the Firebase Realtime Database as a JSON, it was decided that for ease of use, a simple .csv file would be the best method given that Javascript has various libraries which allow for reading these types of files, splitting them and uploading a JSON object to the database.

To be able to read the file, the FileReader class was used along with error handlers which ensure that the integrity of the file was correct, as the data needed to be uploaded with specific headers and number formatting. Due to the development changes in the mobile application and for readability of the data once downloaded, it is required for users of the web application to submit the headers as *"a_lat"* and *"b_lng"* as shown in Figure 4.3.

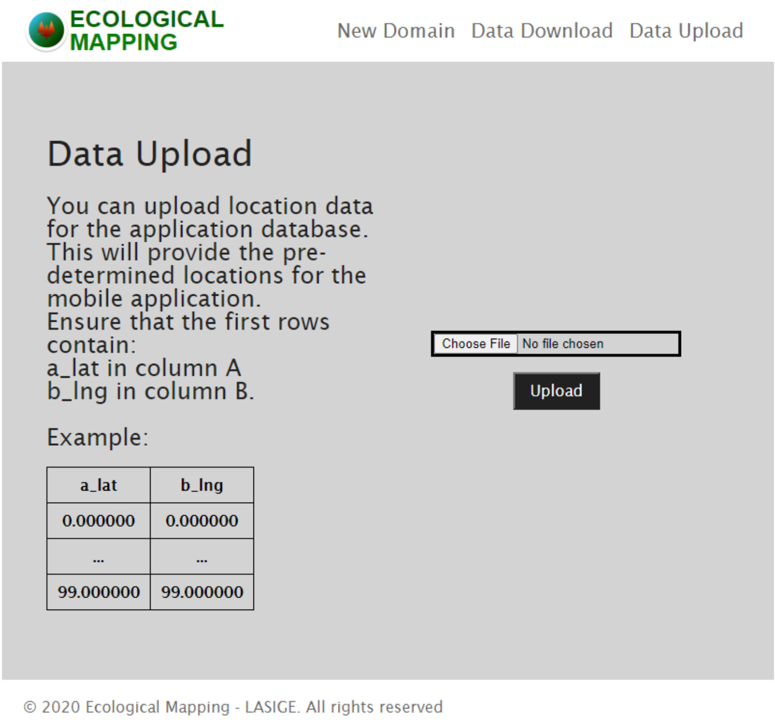

Figure 4.3 Data Upload feature

4.2.3 Data Download

To be able to analyse the data, the owners of the application need to download the data in some format that is easy to analyse without much work required, and also select the data they want to download – this can be seen in Figure 4.4.

For this purpose, it was necessary to ensure the database can provide the data using the methods that exist within Firebase – along with being able to convert this data from the JSON format to the required format, using JavaScript, for the experts to analyse. The requirements to be able to download data are that – first the user must state which domain, they want to download the data from, since all reviews are split into separate domains, and there isn't a way to download from all domains at the moment – and then if they wish to state which dates, they want the data from. There are checks in place to ensure that the application doesn't fail, where if they set a start date that is ahead of the end date, they will receive an error asking them to state a valid date – similarly if there are no reviews in the current domain, it will ask them to select another domain.

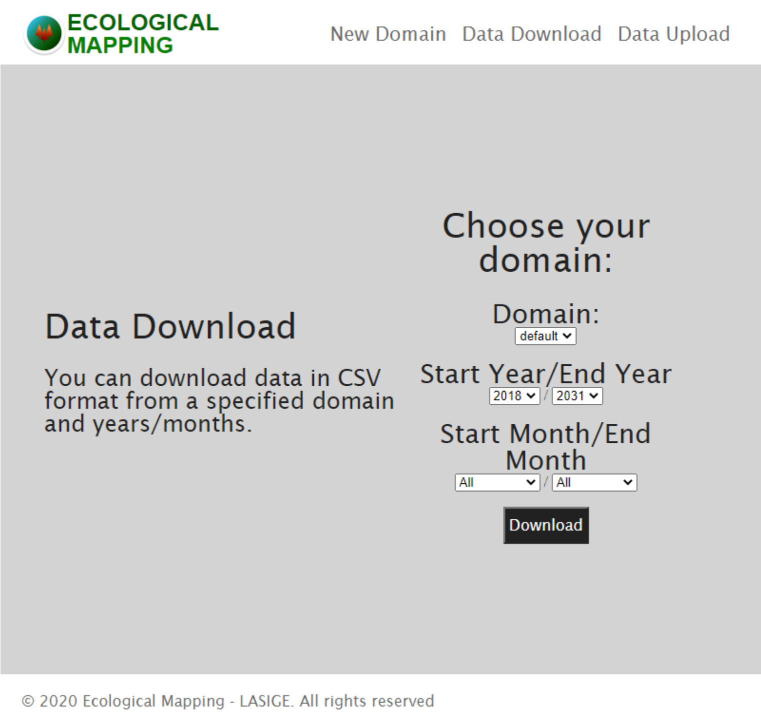

Figure 4.4. Data Download - displayed on web page

It was required to set indexing rules in Firebase to ensure that the data can be sorted, and also to add an epoch timestamp since this allows us to sort the data in an easier fashion. Using the Firebase methods `orderByChild()`, followed by `startAt()` and `endAt()`, along with the indexing and filtering of the data, the web application receives a JSON with all the reviews that have been done ordered by date from oldest to newest. From the JSON, we use the XLSX utilities `json_to_sheet()` method on the JSON, along with an `excelBuffer` to write the data to an .xlsx file and allow the user to download it. To be able to download the file, it was necessary to use the method `saveAsExcel()` using a Blob (to represent raw data, to convert to something readable and process the data) that receives a buffer and exporting a filename with the extension specified at the beginning of the script (.xlsx). Using a Blob, we convert the JSON that was received from the database into an array which can then be exported to a spreadsheet format. During this process, it is also important to state that it was chosen to have the year and month selector in this format as stating an actual date could have proved to be too excessive for the requirements of this application.

4.3 Summary

In this chapter, we discussed the requirements, and the resources and methods used during the development of the web application. Firstly, the requirements were presented to show what was needed from the web application, and second – all the primary features were presented, based on the functional requirements of the web page. In the next chapter we will present our conclusions, including the contributions received throughout the project, skills acquired, along with the challenges faced during the development and future work.

Chapter 5

Conclusion and Future Work

This chapter presents the main contributions of the project as well as the skills that have been acquired. We will also address the challenges that were faced during the development, as well as suggestions for future work.

5.1 Contributions

The two main objectives of this project were achieved, namely, to (1) design, and implement a mobile application to ecologically map locations, and (2) design, and develop a web application to act as support. Users are able to review ecological locations, landmarks, and points that were pre-set by the experts evaluating the ecological locations. The second objective, of designing a web application to act as a support for the mobile application was also accomplished. Those managing the mobile application, can review the information that is gathered by the users in the specified locations that they have set. Finally, a database that connects the Web and Mobile application was developed in this project. This database was implemented in a user-friendly manner, simplifying the method that user collected data on the mobile application is uploaded to the web application, the way it is displayed, and thus facilitating it's download.

5.2 Skills Acquired

Personally, this project allowed for the learning of different tools and languages in creating an application, experience dealing with satellite data, as well as participating in research which mobilizes theoretical and methodological approaches to gamification, and understanding different hedonic and pragmatic qualities which will allow for better data gathering for public good. Throughout the phases of this project, many skills were acquired at different levels:

Development Level: gained knowledge, learning how to design and implement a system involving a mobile application, a web application, and a database – that can be applied in a real-world setting. A more in-depth knowledge of the *Android* system was gained, to be able to structure an application in Java and the libraries provided by the *Android*, Google, and Firebase systems. The knowledge to implement web services using the Firebase system was also gained via both the mobile and web application. The web application also helped achieve a better understanding of *JavaScript*, the use of multiple libraries to allow for upload and download of files, along with the implementation of web services to connect the database. Using the Firebase database, also allowed learning of different types of data formatting (JSON), along with learning how to model a Realtime database. This experience, and the skill set acquired, is one of the most valuable takeaways for future projects.

Software Level: improved knowledge on multiple skillsets for different future projects. Creating vector assets for the application through software such as Adobe Illustrator and Photoshop were valuable skills that can be used outside of the development of applications. Through the use of *Android Studio (Studio64),* many different functions were learned, integration of libraries, Gradle scripts, along with the use of performance, memory, leaks and how to code better were learned using the in-built diagnoses available.

5.3 Challenges

Some of the biggest challenges in this project were to be able to think and work in an environment where it was not possible to meet with the users, but rather hold meetings online due to the pandemic. Consolidating views, and understanding different perspectives of the application could not be done as seamlessly due to the nature of online meetings, and without being able to feel the application. Although working in a multidisciplinary team was a valuable experience, the challenges brought on by online meetings were highlighted in the need for "translation" between experts of different fields – in order to communicate what is required from one standpoint, and what is technically achievable, from the other. Due to this, plenty of prototypes were made, and sent out to be able to implement certain features, understand better the constraints on certain devices (API level, size, etc.) which would have been easier to evaluate in person.

Another challenge was the implementation of the database, and connecting this to both applications (mobile and web) – with the web proving most challenging due to the methods available in the Firebase Realtime Database being vastly different to what was learned during the academic course. Learning to code in JavaScript, implementing libraries, and connecting the database in a manner that allowed the users of the web application to upload and download files in a specific format proved challenging. It was also a valuable learning experience to alter the structure of the database, index the information, receive a JSON object locally, and be able to download the information within the constraints set by the user in the web application.

5.4 Future Work

As with all applications, many additional features and improvements can be implemented. The following were identified elements that were collected throughout the analysis, testing and implementation phases of the development of the application – as well as from the user feedback received.

Android Application:

It was discussed throughout the course of the project that additional features could be implemented. Such as allowing users to swap domains, or changing the default language (English) to any other. The suggestion of different languages being available should be accessible through the side panel that was implemented; along with being set in the login page as this would be useful to users who do not have English as their main language. Another feature that was discussed was the implementation of a system where users can review the same point multiple times, assuring a certain time frame between reviews, that could potentially give better information to the experts conducting the research in these locations.

In order for the application to have better functionality, features could be added, such as allowing the review panel to automatically re-size according to the mobile phone's model. This was a constraint that was hard to implement due to the limitations of the *Android* system, where forcing this – would mean that the application is less accessible to those running the minimum version stated above (API level 26), as this feature is only accessible at API level 30 and above.

As the initial requirement of this application was to develop for both the *Android* and *iOS* operating systems, in the future the application could be implemented using *Flutter*, *React Native, or NativeScript*, all of which are cross platform frameworks that enable the application to be published for both *Android* and *iOS* operating systems. On the other hand, the application can also be developed using *Swift* primarily for the for the *iOS* devices, where it would be required to have upkeep on both systems, and the application may differ.

Web Application:

Although the web application meets the requirements set by the users of the project, the user interface could be improved by having better images, and selection fields. Since the method used by Firebase to return data to the web application is via a sorting function of the timestamp, if the user selects a timeline that includes a month but does not select the starting or ending Year, all of the information from the database will be downloaded. Given this, it would be better to implement a potential initial date, and ending date, that would then retrieve the data from the application.

The web application, at the moment contains no added security features, or an authentication to add data to the database, therefore it would be important to include an authentication method for an administrator. This was not defined in the requirements of the web application, as although it is hosted on the web, the link is hidden from search tools. This can be accomplished quickly by having a .htpasswd file or other similar method to protect the website from access via a direct link.

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